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The Integration of Technology in Ratio and Proportion Learning: A Systematic Literature Review

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Abstract

Ratio and proportion are fundamental topics in mathematics taught from elementary school to college, with significant relevance in education and everyday life. This study aims to systematically review technology-based innovations in ratio and proportion learning over the past 13 years. A Systematic Literature Review method was used to identify, synthesize, and analyze 23 journals published between 2012 and 2025, utilizing the Scopus and Google Scholar databases. This literature review consists of three main stages: planning, implementation, and reporting the review. The analysis results show that the most dominant type of technology used is Game-Based Learning, followed by Web-Based Platforms. These technologies have significantly contributed to improving mathematical skills such as proportional reasoning, problem-solving, critical thinking, creativity, and communication, especially among elementary and secondary school students. Proportional reasoning was noted as the key skill most developed through the application of these technologies. Based on these findings, further research is recommended to design interventions that integrate technology and local culture, employ contextual and realistic approaches, and also consider affective domains, such as self-confidence, motivation, and values, which are still under-researched but play a crucial role in technology use. This is expected to significantly contribute to creating more meaningful and accessible learning experiences.

Keywords: ratio and proportion, technology, systematic literature review

INTRODUCTION

A ratio is a comparison between two quantities expressed as a multiplication (Behr et al., 1992; Langrall & Swafford, 2000; Petit et al., 2020). Meanwhile, a proportion is a relationship that shows the similarity between two ratios, where the ratio of two quantities remains constant despite changes in the related quantities (Lobato et al., 2010). Proportions are generally symbolized as a/b = c/d or a : b = c : d (Ben-Chaim et al., 2012; Lamon, 2020). Ratios and proportions are fundamental topics in mathematics education,

which play an important role in the mathematics curriculum at both elementary and secondary levels (Bintz & Moore, 2020; Dole et al., 2012) Therefore, an understanding of ratios and proportions is introduced from an early age, which serves as a foundation for further studying these concepts and applying them in everyday life (Andini & Jupri, 2017; Muttaqin et al., 2017). Implementation of the topic of ratios and proportions can also be found in various other mathematical topics, such as rational numbers (fractions, decimals, and percentages), linear algebra, linear models in calculus and statistics, and others (Vanluydt et al., 2021; Walle et al., 2020). In everyday life, ratios and proportions play a very important role in situations such as price comparisons, the use of scales in maps and building designs, and percentage calculations (Izzatin, 2022). This topic is also highly relevant to a number of professions, including architecture, nursing, and pharmacy (Hilton et al., 2016; Nugraha et al., 2016).

Although ratio and proportion are important topics in mathematics education, they also present challenges for both teachers and students (Ezaki et al., 2024). Teachers and students experience similar difficulties with this topic (Copur-Gencturk & Tolar, 2022), especially in understanding the relationship between two proportional quantities (Copur-Gencturk et al., 2023; Orrill & Brown, 2012), and comparing proportional and non-proportional situations (Izsák & Jacobson, 2017). Students' understanding or conception of ratio is influenced by prior knowledge, didactic practices, or lack of context (Biori et al., 2022; Wahyuningrum et al., 2019). One contributing factor is the minimal use of context and visual media in helping students understand the concept of ratio and proportion (Nasution et al., 2014). Several studies have begun to address the topic of ratio and proportion, focusing on instructional design, technology use, and the development of teaching materials (Risdiyanti et al., 2024). These are solutions and innovations to overcome obstacles in understanding ratio and proportion concepts. Sugiarni et al. (2025) stated that to minimize these barriers, teachers can present material or problems using various strategies, one of which is through the use of visual media or mathematical modeling. For example, utilizing technology that plays a role in understanding mathematical concepts and can serve as a theoretical construction medium for students' understanding of different mathematical concepts (Pansell, 2023; Semenikhina et al., 2018). This greatly supports students in developing effective learning opportunities (Thurn et al., 2022), particularly in understanding the concepts of ratio and proportion, so that activities involving technology can stimulate students' proportional reasoning. Frith & Lloyd (2016) emphasized that this skill is essential for enabling critical understanding.

Technology makes mathematics teaching more enjoyable, effective, and efficient (Lou et al., 2001), such as using applications like PowerPoint, Geometers, Liveworksheets, Sketchpad, Cabri Jr, and virtual manipulatives (Li & Ma, 2010), as well as educational games, which are currently trending like Scratch. This technology helps engage student participation and enhances students' understanding and knowledge through visualization (Nurulaini et al., 2022). To address this issue, innovation in teaching strategies and technology is crucial. Various studies have shown that the use of technology in mathematics education can enrich students' learning experiences and support their understanding of mathematical concepts, including proportional reasoning.

Technologies used in mathematics instruction, such as interactive visualization tools, simulation-based learning software, and internet-based applications, can help students understand the relationships between variables in a more visual and concrete way (Çetin & Kocakaya, 2019). These strategies and technologies allow students to experiment with different scenarios and gain firsthand experience in observing and understanding proportional concepts. Therefore, the success of learning innovations greatly depends on the readiness and support provided to educators to adapt and integrate these new methods into their teaching practices.

Several previous studies related to systematic literature reviews on the topic of ratio and proportion have been conducted, but there are still gaps that need to be addressed in the existing literature. The first study by Risdiyanti et al. (2024) discussed the learning of ratio and proportion through the *Pendidikan Matematika Realistik Indonesia* (PMRI) or Realistic Mathematics Education (RME). Next, Sari et al. (2025) reviewed the focus of previous research on learning ratio and proportion, although it was still limited to the methodological aspects used in the learning. Elias et al. (2025) continued by conducting a systematic literature review on the topic of proportionality in mathematics, but this study did not explicitly touch on the use of technology. Lutfi et al. (2024) examined the development of proportional reasoning in mathematics learning and the technology used in that context, but this study was also limited to the aspect of developing reasoning skills and did not analyze the effects of technology use in depth. This study will focus on the implementation of technology in learning ratio and proportion, and analyze the potential effects that arise on the development of students' mathematical skills. Thus, this study offers a new contribution by exploring the use of technology in more depth in learning the topic of ratio and proportion, which has not been widely discussed in previous studies.

This study explicitly aims to: 1) identify and classify the types of technology used in ratio and proportion learning, 2) analyze the development of the number of publications related to ratio and proportion learning using technology during the period 2012 to 2025, distribute the number of countries conducting research, and classify the dominant types of research on this topic, and 3) classify the most developed mathematical skills at each level of education based on the application of technology in ratio and proportion learning. This literature review is expected to provide clearer insights into technological innovations that have proven effective in ratio and proportion learning. In addition, this study is expected to provide recommendations for further development in the context of mathematics education, especially in Indonesia, with an emphasis on interventions and implementation of technology that is trending and relevant in the mathematics learning process, as well as having an impact on mathematics skills in the 21st century. Mathematics skills such as proportional reasoning, problem solving, creative thinking, and communication, as well as affective aspects that often have not received adequate attention in mathematics learning. The integration of technology in learning is expected to make a significant contribution to the development of these skills, which in turn can enrich the mathematics learning process at various levels of education.

METHODS

This study employs a systematic literature review (SLR) method with a descriptive qualitative approach. In this study, a Systematic Literature Review (SLR) approach was chosen to identify technological innovations applied in learning the topic of ratio and proportion, as explored in previous studies. The PRISMA framework was used to ensure transparency and accuracy in the selection process and analysis of relevant articles. The SLR compiles the literature in a structured and systematic manner, providing a comprehensive overview of the implementation of various innovations, particularly the types of technology used and the development of mathematics skills. These findings help researchers draw more in-depth conclusions and provide a strong foundation for designing more effective educational interventions and guiding further research. The literature review in this study consists of three main stages: planning the review, conducting the review, and reporting the review (Brereton et al., 2007; Kitchenham & Charters, 2007). The review process followed in this study adhered to eight common steps: (1) formulating the research problem; (2) developing and validating the review protocol; (3) searching for literature; (4) screening data for inclusion; (5) assessing quality; (6) extracting data; (7) synthesizing the results; and (8) reporting the findings (Xiao & Watson, 2019). The stages undertaken in this study can be seen in Figure 1.

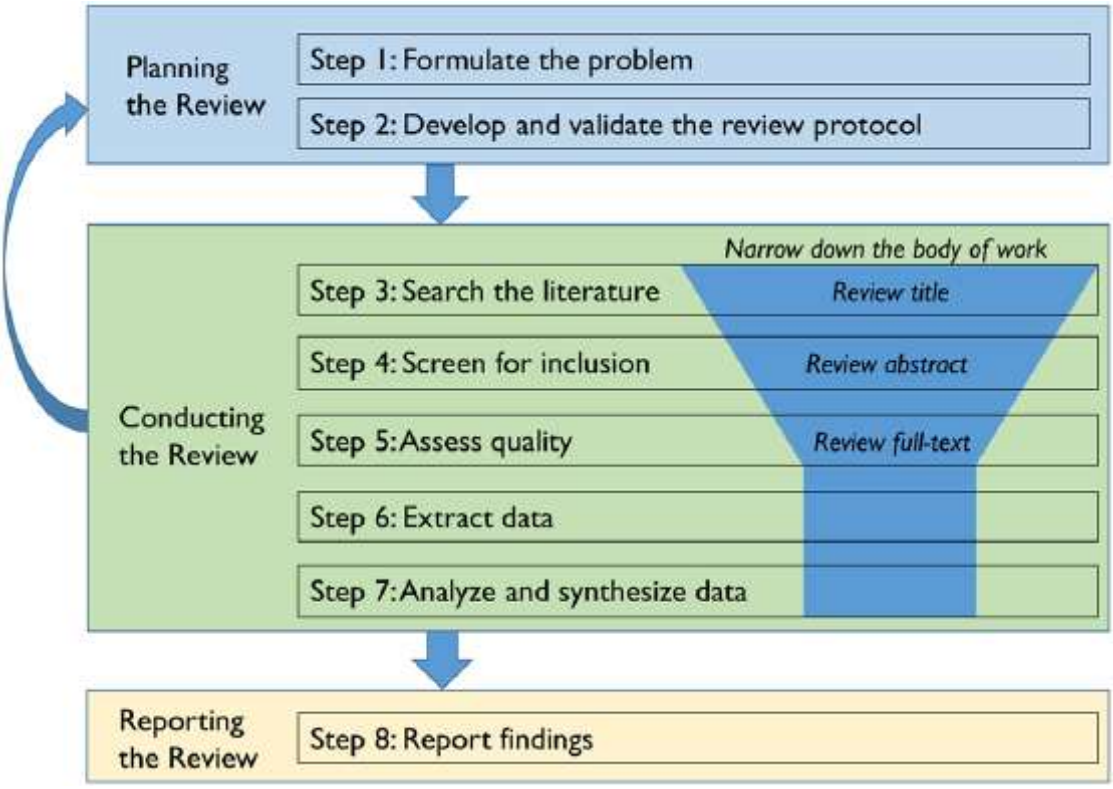

Figure 1. Stages of the SLR Process

Planning the Review

In this stage, the review process begins with conducting a research investigation, which is explored through research questions. Therefore, the research questions drive the entire literature review process (Kitchenham & Charters, 2007; Xiao & Watson, 2019). The research questions are as follows:

RQ1: What types of technology are used in ratio and proportion learning?

RQ2: How does the number of publications related to learning ratios and proportions using technology develop each year, the distribution of the number of countries conducting research, and the dominant types of research on this topic?

RQ3: What are the most developed mathematical skills at each level of education based on the application of technology in learning ratios and proportions?

Next, the review protocol is developed. This involves establishing guidelines for the inclusion and exclusion of studies, defining search terms, selecting appropriate databases, and setting criteria for assessing the quality of the included studies. These steps ensure that the review process is structured and systematic, allowing for a comprehensive and objective evaluation of the existing literature. The researcher made three important decisions regarding the selection of keywords, database selection, and inclusion and exclusion criteria (Khizar et al., 2023; Xiao & Watson, 2019). The databases used in the literature search were Google Scholar and Scopus, as both cover a broad and relevant range of articles related to this research topic and have a good reputation for providing up-to-date scientific literature. Google Scholar offers access to a wide variety of publications, while Scopus provides a more curated selection of articles with a structured citation measurement system. Although ERIC and Web of Science (WoS) are also relevant, Google Scholar and Scopus were chosen to ensure a broader and more diverse coverage of the literature within the context of this study.

Conducting the review

At this stage, the process consists of search literature, screen for inclusion, assess quality, extract data, and analyze and synthesize data (Xiao & Watson, 2019). As the primary source, Scopus is applied in this study to identify relevant literature that will be included in the literature review. Additionally, Google Scholar serves as a supplementary database to obtain other articles related to the research topic. In addition to ensuring relevance, this study also considered methodological aspects as part of the article quality assessment, including research design, data collection methods, and data analysis techniques. This evaluation strengthened the theoretical and empirical foundations of the literature review, thus providing a more significant contribution to the research. The inclusion and exclusion criteria to ensure the relevance and quality of the literature used are presented in Table 1.

Table 1. Search keywords, database, inclusion and exclusion criteria

Database	**Scopus; Google Scholar**
Title word	"Ratio", "Proportion"
Keywords	"Ratio" and "Technology", "Proportion" and "Technology"
Inclusion Criteria	Relevant Topic: The research should address a topic that aligns with the objectives of the literature review.
	Reference Sources: The references should be based on keywords, titles, abstracts, and full texts.
	Time Range: The review should consider research published in the last 13 years.

Database	**Scopus; Google Scholar**
	Language: The articles used should be in English. Source Quality: The articles should be published in Scopus and Google Scholar databases.
	Type of Source: The sources may include journal articles and conference proceedings.
Exlusion Criteria	Irrelevant Topic: Research that does not align with the main topic of the literature review will be excluded.
	Incomplete Data: Articles without complete data or those that only include abstracts will be excluded.
	Publication Year: Articles published outside the specified time range may be excluded unless there is a valid reason.
	Language: Articles in languages that the researcher does not understand, without translation, may be excluded.
	Quality and Credibility: Articles from non-credible sources or journals with low indexing will be excluded.

The initial screening was conducted using titles, keywords, and databases relevant to the last 13 years (2012-2025), which led to the identification of 145 documents from Scopus (n = 7) and Google Scholar (n = 138), as presented in Table 2.

Table 2. Search Results Based on Database, Title, Keywords, and Publication Year

Title word	**keywords**	**Scopus**	**Google scholar**
"Ratio"	"Ratio" and "Technology"	3	89
"Proportion"	"Proportion" and "Technology"	4	49
Total documents		7	138
Total of all documents			145

The review process begins with searching for literature, screening the data for inclusion, assessing quality, extracting data, and analyzing and synthesizing the data. The keywords used for data search were "ratio" and "technology" and "proportion" and "technology". Initial data screening was conducted using relevant keywords, titles, and databases, which resulted in the identification of 145 documents 7 from Scopus and 138 from Google Scholar. Subsequently, the articles were reviewed, and duplicates or inaccessible documents were removed, resulting in 97 remaining documents. The researcher then analyzed the titles and abstracts of these documents using the inclusion and exclusion criteria to ensure relevance to the research questions and scope of the study. This stage allowed the researcher to refine the set of studies to be included in the systematic literature review. The researcher identified 50 documents that met the criteria, then reduced 16 documents that were not relevant. Subsequently, from the 34 eligible documents, 23 were selected to address the research questions. These 23 documents include seven from the Scopus database and sixteen from Google Scholar. The researchers employed a rigorous and meticulous selection process to synthesize the literature comprehensively. For a visual representation of the document selection process, please refer to Figure 2.

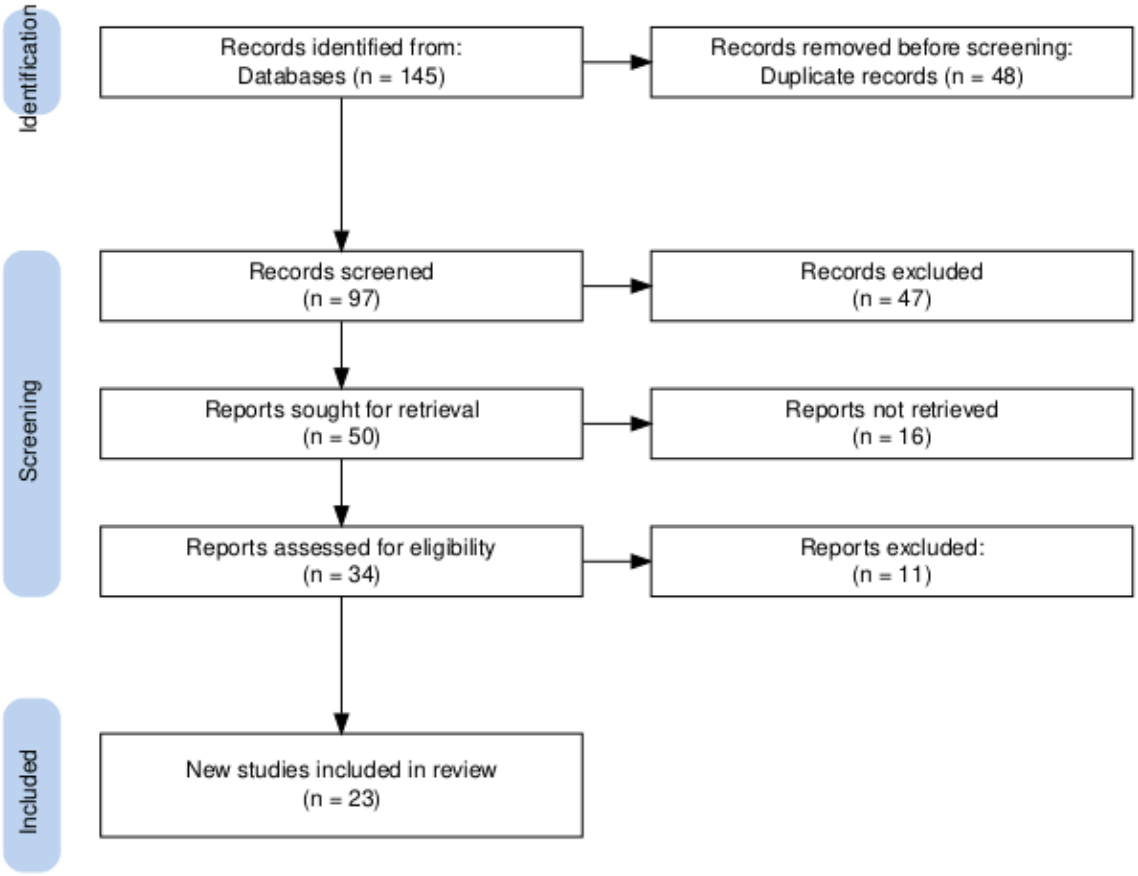

Figure 2. Article Screening Process Using PRISMA

After selecting 23 relevant documents for further review and analysis, each article was organized based on several dimensions, including author names, publication year, publication source, title, country of origin, content discussed, and technologies used. A specialized database was developed using MS Excel to facilitate data extraction. Subsequently, the researcher employed quantitative analysis to evaluate the 23 articles that were deemed suitable for answering the research questions. This process helped in systematically categorizing and synthesizing the findings from the selected studies.

Reporting the Review

Creating a reliable and replicable literature review involves providing comprehensive documentation of the systematic study, which must detail the rationale behind each inclusion and exclusion criterion. Furthermore, it is important to report the findings of the literature search, screening, and quality assessment. The findings of this review are analyzed using content analysis, and the review report is structured as follows: first, a quantitative descriptive analysis of the literature profile; second, a network analysis; third, a qualitative literature analysis; and fourth, a critical review analysis.

RESULTS AND DISCUSSION

In this section, the researchers present a synthesis of 23 articles included in the systematic literature review (SLR) related to the use of technology in teaching ratio and proportion. This synthesis is divided into five main categories: code, author name, year of study, article title, country of origin, and technology used. The findings of this study aim to provide deeper insights into the implementation of technology used to support the teaching of ratio and proportion over the past 13 years globally. The selection of the past 13 years covers significant developments in the adoption of educational technology, reflects the latest trends in learning, as well as the evolving mathematical capabilities in teaching ratio and proportion. Table 3 presents a detailed synthesis of these items.

Table 3. Journal Identity, Content, and Technology Used in the Literature

Code	Author (s)	Year	Title	Country	Technology
A-1	Kaplan & Ozturk	2012	The effect of computer based instruction method on instruction of ratio-proportion and development of proportional reasoning	Turkey	Innovative computer-based instruction using Vitamin Computer software
A-2	Valdez, et al.	2013	Math snacks: using animations and games to fill the gaps in mathematics	USA	Computer animation and web-based educational games: Math Snacks
A-3	Hilton, et al.	2013	Using Digital Photography To Support Teaching And Learning Of Proportional Reasoning Concepts	Australia	Digital cameras, especially flip cameras
A-4	Ruiz	2014	Virtual learning environment of the proportion topic in primary school students	Mexico	Virtual learning environment (VLE) that uses the SCORM (sharable content object reference model) version 1.2 standard
A-5	Vandercruys, et al	2015	"Zeldenrust": a mathematical game-based learning environment for prevocational students	Belgium	Game-based learning environment (GBLE)
A-6	Alfieri, et al	2015	Case studies of a robot-based game to shape interests and hone proportional reasoning skills	USA	A 3D computer-based game called expedition atlantis
A-7	Courey, et al	2015	The effects of using dynabook to prepare special education teachers to teach proportional reasoning	USA	Interactive website: dynabook
A-8	Vandercruys, et al	2016	The effectiveness of a math game: The impact of integrating conceptual clarification as support	Belgium	Zeldenrust: a mathematical game-based learning

Code	Author (s)	Year	Title	Country	Technology
A-9	Vandercruys, et al	2017	Content integration as a factor in math-game effectiveness	Belgium	Zeldenrust: a mathematical game-based learning
A-10	Bell & Gresalfi	2017	Teaching with Videogames: How Experience Impacts Classroom Integration	USA	Integration of digital games: Boone's Meadow
A-11	Oktavianingtyas, et al	2018	Development 3D animated story as interactive learning media with lectora inspire and plotagon on direct and inverse proportion subject	Indonesia	Lectora inspire and plotagon
A-12	Ke	2019	Mathematical problem solving and learning in an architecture-themed epistemic game	USA	Game simulasi 3D berbasis epistemic: game E-rebuild
A-13	Arican, & Özçakir	2021	Facilitating the development of Preservice teachers' proportional reasoning in geometric similarity problems using augmented reality activities	Turkey	Augmented Reality (AR), specifically using the Vuforia AR SDK
A-14	Maryam, & Sampoerno	2021	The development of interactive learning media with realistic mathematics education approach for topic of ratio and proportion	Indonesia	Adobe flash professional CS6
A-15	Ortiz, et al.	2022	Promoting proportional reasoning with the support of digital technology	Mexico	Virtual interactive didactic scenarios (VIDS),
A-16	Gündoğdu & Tunç	2022	Improving middle school students' proportional reasoning through stem activities	Turkey	STEM activities, such as Scratch and mBlock,
A-17	Cuevas-Vallejo, et al.	2023	Promote proportional reasoning through digital technology	Mexico	Interactive virtual teaching environments (EDVIs), designed using GeoGebra
A-18	Casler-Failing & Swann	2023	Developing proportional reasoning via lego robotics: experiences of a 7th grade mathematics class	USA	LEGO robotics
A-19	Guntur, et al.	2023	The learning trajectory based on STEM of elementary school pupils in solving proportion material: didactical design-research	Indonesia	STEM-based learning media
A-20	Harini, et al.	2023	Effectiveness of E-worksheets on problem-solving skills: a study of students' self-directed learning in the topic of ratios	Indonesia	Liveworksheet platform
A-21	Ledesma, et al.	2024	Proposal of a system to support the learning of fractions, ratio, and	Mexico	Web-based system

Code	Author (s)	Year	Title	Country	Technology
			proportion in elementary school students		
A-22	Mankhong & Pimvichai	2024	Impacts of creative-stem education integrated with tpack on grade 7 students' academic achievement, problem-solving skills, creative thinking skills, and communication skills in ratio, proportion, and percentage in mathematics	Thailand	STEM education, Creativity-Based Learning (CBL), and Technological Pedagogical and Content Knowledge (TPACK): Google Forms, YouTube, Kahoot, Wordwall, Mentimeter, Canva, and Capcut
A-23	Mayangsari, et al	2025	Google sites-problem-based learning: a media to support proportion learning	Indonesia	Google Sites

Types of technology used in learning the topic of ratio and proportion

In a review of 23 articles, various types of technology used to support learning on ratio and proportion topics can be classified based on the type of technology applied. Technologies include computer and web-based platforms, educational games, Augmented Reality (AR), Virtual Reality (VR), STEM technology, multimedia tools, and robotics (as seen in Table 4 and percentages in Figure 3).

Table 4. Technology Type Classification

Technology Type	Code Article
Computer and Web-Based Platforms	A-1, A-7, A-20, A-21, A-23
Game-Based Learning	A-2, A-5, A-6, A-8, A-9, A-10, A-12,
Virtual Reality (VR)	A-4, A-15, A17
Augmented Reality (AR)	A-13
Tools Multimedia	A-11, A-14, A-3
STEM Technology	A-16, A-19, A-22
Robotics	A-18

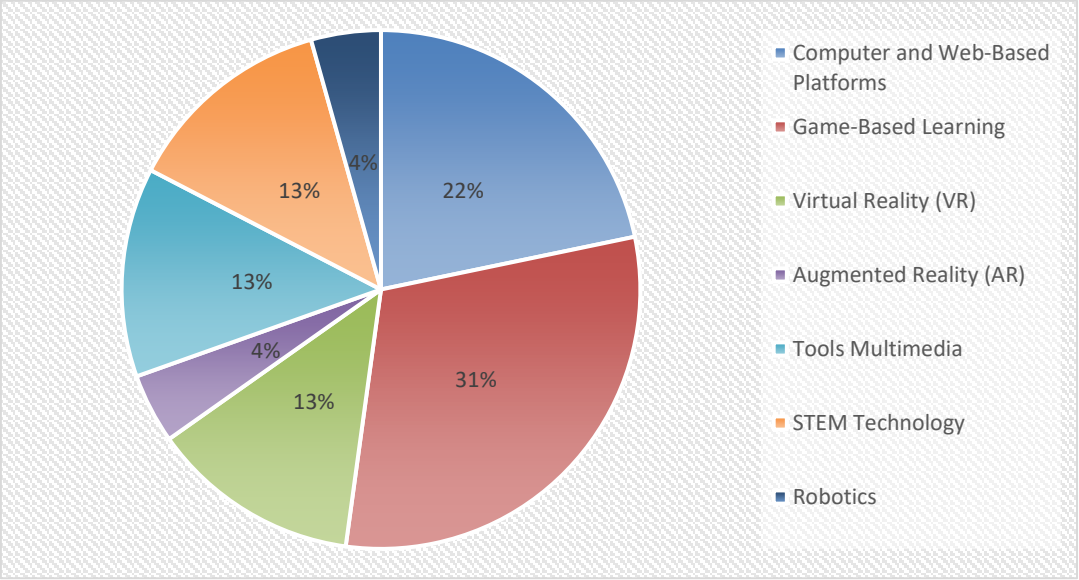

Figure 3. Mapping of Technology Types in Research

Table 4 and Figure 3 show the various types of technology used in research related to learning the topic of ratio and proportion. Based on the analysis of the identified technologies, Game-Based Learning (GBL) was the most dominant technology type in supporting learning, with a percentage of 31%. This finding is due to the fact that GBL is one of the modern trends in education in the 21st century (Hui & Mahmud, 2023), thus receiving increasing academic attention in recent years (Zou, 2020). In this study, games like Math Snacks, Zeldenrust, Expedition Atlantis, and E-rebuild significantly increased student engagement in learning through interactive experiences. Relevantly, GBL creates a balance between classroom learning and educational games while increasing learning efficiency through student-centered learning activities (Lasut & Bawengan, 2020). In addition, GBL was identified as a suitable tool to improve students' achievement and affective domain in mathematics learning (Vankúš, 2021).

Furthermore, computer and web-based technologies also play a significant role in learning, accounting for 22% of the learning process. Applications such as Vitamin Computer Software, Liveworksheet, Google Sites, and other web-based platforms are used to provide materials and support the online instructional process. These tools are effective in delivering materials through a web-based interface (Oumelaid et al., 2023). In addition, teachers can use the website to communicate with students and parents, as well as post assignments and other important information (Shana et al., 2024; Sugiharni et al., 2022). The use of web-based systems and interactive platforms like Dynabook also reflects the increasing use of technology to support more flexible and integrated learning, meeting today's teaching needs. Computer- and web-based technologies facilitate real-time mathematics learning and replicate interactive learning environments (Ion & Popescu, 2025).

Virtual Reality (VR) technology, multimedia tools, and STEM technology each accounted for the same percentage, at 13%. VR is increasingly being introduced as a more immersive learning method, as seen in the use of VLEs with SCORM standards and virtual interactive didactic scenarios (VIDS). Relevantly, VR is crucial for advancing mathematics learning (Lai & Cheong, 2022). VR significantly enhances meaningful learning experiences (Koparan et al., 2023) and has shown additional intrinsic benefits in increasing student motivation (Cai et al., 2021; Chang & Yu, 2018). Meanwhile, STEM technology using applications like Scratch, mBlock, and Google Forms introduces approaches based on science, technology, engineering, and mathematics. Multimedia tools like Lectora Inspire and Adobe Flash Professional CS6 are used to develop more engaging and interactive learning media, supporting the visualization of abstract mathematical concepts. This technology also aligns with multimedia approaches that have been proven to enhance learning effectiveness through the combination of text, images, and sound (Mayer, 2017).

Finally, Robotics and Augmented Reality (AR) each account for 4%. The use of LEGO Robotics adds a practical dimension to learning, giving students the opportunity to apply mathematical concepts in practical activities and robot-based projects. LEGO® Robotics has demonstrated superior performance based on evaluation criteria such as modularity, hardware, curriculum, price, and other related factors (Souza et al., 2018), so

that they play an active role in mathematics learning (Zhong & Xia, 2020), by combining abstract mathematical concepts with modern technology (Szilágyi et al., 2025). Augmented Reality (AR), specifically using the Vuforia AR SDK, has the added advantage of compensating for impairments in some senses by adding useful information to the real world. This allows users to gain additional, relevant information without compromising their interaction with their surroundings (Ioannou & Constantinou, 2018).

Publication Trends, Country Distribution, and Types of Research in Ratio and Proportion Learning Using Technology

The development of publication trends related to the topic of ratio and proportion with the use of technology over the last 13 years can be seen in Figure 4.

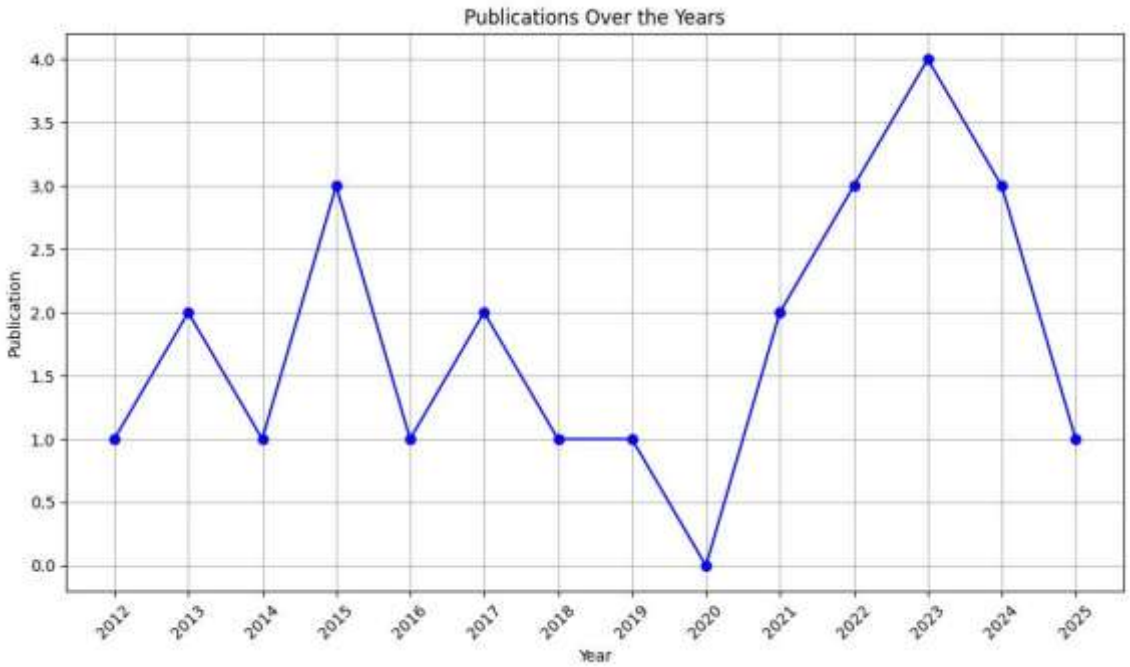

Figure 4. Publication Trends related to Topic Ratio and Proportion with Technology Use (2012-2025)

Based on Figure 4, the analysis of published data regarding the use of technology in learning the topic of ratio and proportion shows a clear trend throughout the period from 2012 to 2025. This is because the use of technology offers innovative ways for students to learn and engage with mathematics learning (Attard & Holmes, 2022). The first publication appeared in 2012 with a single document. Subsequently, there was an increase in publications in 2013 and 2015 with two and three documents, respectively. However, the number of publications experienced a significant decline in the period from 2016 to 2019, with only one publication per year. The peak number of publications was recorded in 2023, which indicated a surge in attention to this topic with four published documents. Since the COVID-19 pandemic, it can be said that the use of technology in education is no longer an option, but rather an essential tool for developing the quality and effectiveness of relevant mathematics education (Engelbrecht & Borba, 2024;

Kimmons, 2020). However, in 2024 and 2025, the number of publications decreased again to two and one documents, respectively. Overall, despite fluctuations in the number of publications, the ongoing continuity of research indicates that this topic remains a focus for researchers committed to contributing to the development of technology-based ratio and proportion learning. This indicates that despite the variation in the number of publications, the quality and sustainability of research in this field are maintained. In response to the popularity and importance of technology use, various research continues to be conducted in mathematics education (Hwang et al., 2023), such as educational robotics (Zhong & Xia, 2020) tablets (Svela et al., 2019) and mathematics-specific technology (Yohannes & Chen, 2023).

The mapping of countries, years, and technologies used in teaching the topic of ratio and proportion can be seen in Figure 5.

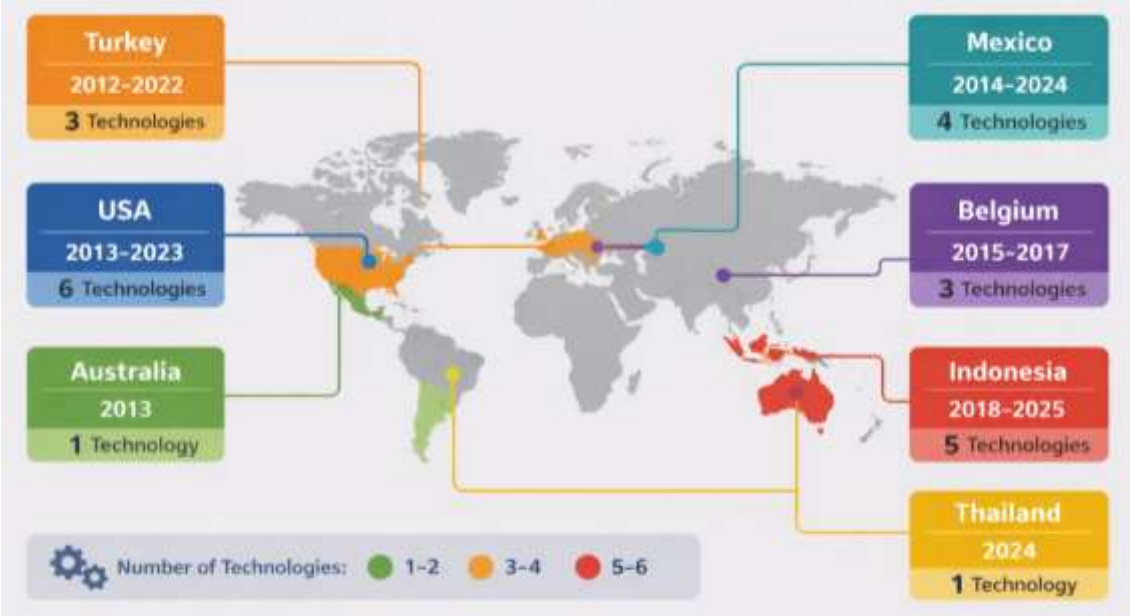

Figure 5. Mapping of countries, years and number of technologies used

Based on Figure 5, the United States recorded the highest number of technologies implemented between 2013 and 2023, with six technologies. This reflects the country's strong focus on technology development and implementation during that time. Consistent with these findings, developed countries like the United States have prioritized technology integration in their educational curricula to support more effective and relevant learning (Sacristán, 2024). Meanwhile, Indonesia recorded 5 technologies implemented in the period 2018 to 2025, showing significant efforts in technology development in recent years, with projections continuing until 2025. This is because as a developing country, Indonesia faces the need for educators to exert additional efforts in integrating technology into mathematics teaching (Hidayat & Firmanti, 2024). Mexico, in the period from 2014 to 2024, implemented 4 technologies, which shows that the country is trying to increase the use of technology gradually in a relatively short period. Because the integration of Technology in learning The implications are discussed in the

context of the National Development Plan (2013-2018) for Mexico (Castillo et al., 2016). Furthermore, Turkey, which recorded three technologies implemented from 2012 to 2022, demonstrates consistent technology adoption, albeit with fewer technologies than other countries. Similarly, Belgium implemented three technologies between 2015 and 2017, indicating a short-term focus on technology development. Australia implemented only one technology in 2013, which may reflect an earlier or more limited technology adoption phase in that year. In developed countries, technology has become an integral part of the education system (İncikabı & Tjoe, 2013).Meanwhile, Thailand, which is expected to begin implementing only one technology in 2024, demonstrates that the country is still in the early stages of technology application on the topic of ratios and proportions. This presents a challenge in developing countries due to limited access (Sacristán et al., 2021).

The mapping of the types of research used in technology integration on the topic of ratio and proportion is shown in Figure 6.

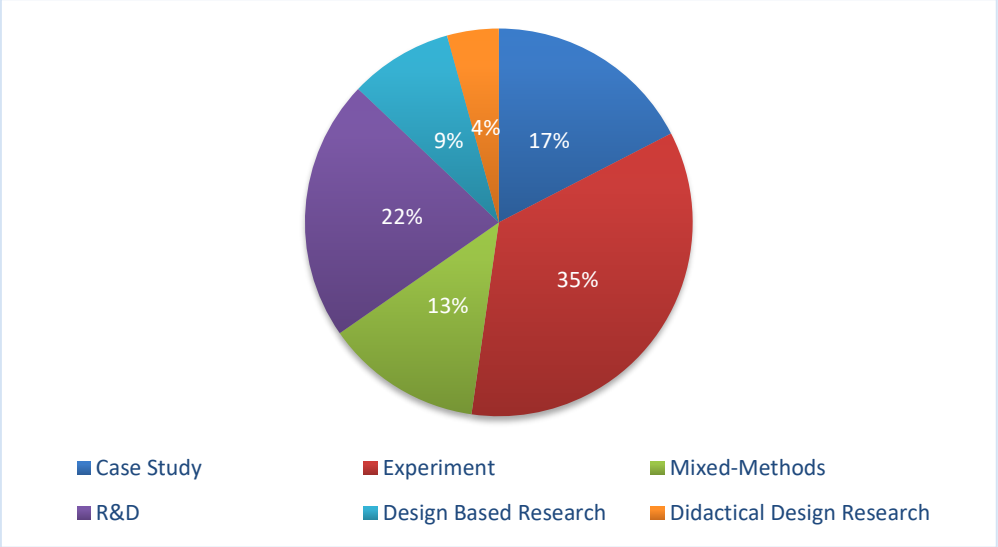

Figure 6. Mapping of Research Types

Figure 6 shows that the most common type of research conducted on the topic of ratios and proportions using technology is experimental research, with the largest percentage reaching 35% (8 document) used in research Kaplan & Ozturk (2012); Valdez et al. (2013); Ruiz (2014); Alfieri et al. (2015); Vandercruysse et al. (2016); Vandercruysse et al (2017); Harini et al. (2023); and Mankhong & Pimvichai (2024). This type of research shows a dominant quantitative approach that focuses on testing and measuring the impact of technology. After that, the type of R&D (Research and Development) research follows with a percentage of 22% (5 document), indicating a focus on developing new technology-based learning tools or methods to improve the quality of teaching on this topic. R&D is carried out on research Vandercruysse et al. (2015); Oktavianingtyas et al. (2018); Maryam & Sampoerno (2021); Ledesma et al. (2024) and Mayangsari et al. (2025). Case studies or qualitative approaches contribute 17% (4 document), indicating the use of a more in-depth approach to understand the experiences of individuals or groups. Research conducted on Hilton et al. (2013); Bell &

Gresalfi (2017); Arican & Özçakir (2021); and Gündoğdu & Tunç (2022). The type of mixed-methods research contributes 13% (3 document), indicating that some studies combine qualitative and quantitative approaches to gain a more comprehensive understanding. Mixed-methods research was conducted on Courey et al (2015); Ke (2019) and Casler-Failing & Swann (2023). Meanwhile, Design-Based Research (DBR) and Didactic Design Research (DDR) have smaller contributions, respectively 9% (2 document) in research Ortiz et al. (2022) and Cuevas-Vallejo et al. (2023) and 4% (1 document), in research Guntur et al. (2023) indicating that although useful in designing and implementing innovative learning solutions, these two types of research are less dominant in this topic.

The Development of Mathematical Skills at Each Level of Education Based on the Application of Technology in Learning Ratio and Proportion

The types of research used in the topic of technology-assisted ratios and proportions are shown in Figure 7.

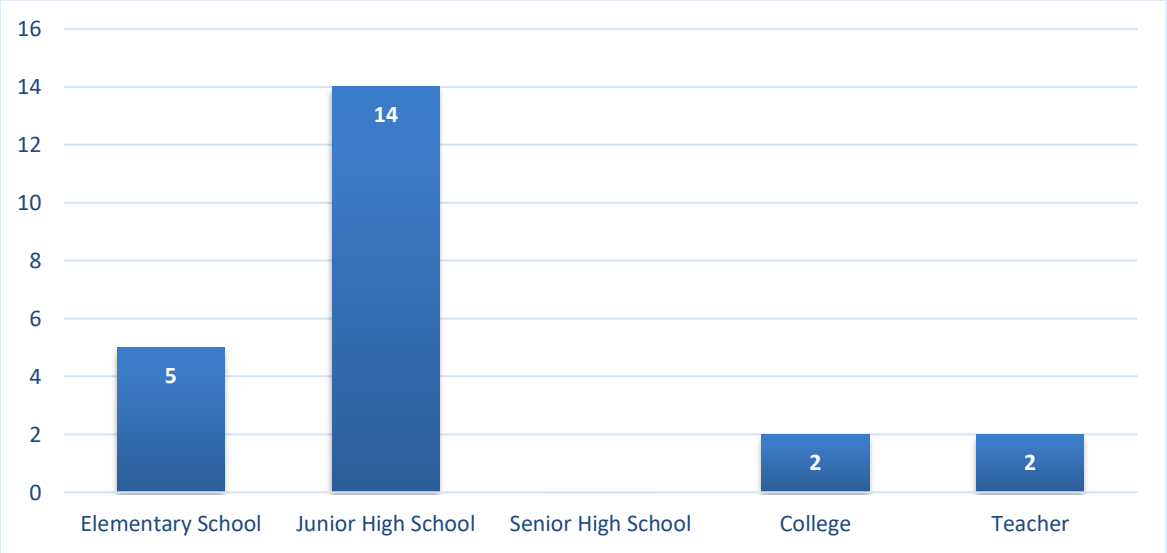

Figure 7. Mapping of Unit Levels Based on Education Level

Based on Figure 7, it shows that the application of technology related to this topic is more dominant at the Junior High School level, with a much higher frequency compared to other educational levels, with 14 documents. This reflects a greater focus or need at this educational level in the context of the development and application of the topic studied. Relevant to this finding, learning ratio and proportion is emphasized in secondary school students because proportional reasoning is considered to be well developed (Singh, 2000; Wahyuningrum et al., 2017). Furthermore, the elementary school level with a total of 5 documents, which indicates the topic of ratio is starting to be introduced to elementary school students, because this topic is essential in learning mathematics (Ben-Chaim et al., 2012; Simon & Blume, 1994). In addition, the frequency at other educational levels, such as universities and teachers, which is lower indicates that the topic discussed may not have been widely applied or researched at this educational level, or there are certain factors that limit its adoption or application. In high school,

almost no research at all. Relevant to these findings, the integration of ratio and proportion topics into the curriculum for secondary school students, especially those aged 12 to 15, is crucial, given that at this age range, students' cognitive development is undergoing a transition from the concrete operational stage to the abstract or formal operational stage (Maryam & Sampoerno, 2021; Vanluydt et al., 2019).

Integrating technology into learning about ratio and proportion can play a vital role in supporting the development of various mathematical skills. The following presents a mapping of mathematical skills related to ratio and proportion based on the reviewed research articles, as shown in Table 5.

Table 5. Mapping of Mathematical Skills Based on Research Articles

Mathematical ability	Code article
Proportional reasoning	A-1, A-3, A-4, A-5, A-6, A7, A-9, A-13, A-15, A-16, A-17, A-18
Problem Solving	A-10, A12, A-20, A-22
Creative Thinking	A-22
Communication	A-22

Based on Graph 7 and Table 5 shows the distribution of mathematical abilities used in the topic of ratio and proportion with technology. The mathematical abilities studied in various articles include proportional reasoning, problem solving, creative thinking, and communication with various technological applications. Proportional reasoning is the most researched ability recorded in 13 documents, which shows that the development of proportional reasoning is a primary focus in research involving students at the Junior High and Elementary School levels. Students' proportional reasoning significantly increased using several types of Computer and Web-Based Platform technologies such as vitamin computer software (Kaplan & Ozturk, 2012); Multimedia Tools using digital photography to support teaching and learning (Hilton et al., 2013); game-based learning in the form of Zeldenrust (Vandercruysse et al., 2015, 2017); AR using the Vuforia AR SDK (Arican & Özçakir, 2021); VR in the form of virtual interactive didactic scenarios (VIDS) (Ortiz et al., 2022); Interactive virtual teaching environments (EDVIs), designed using GeoGebra (Cuevas-Vallejo et al., 2023) and virtual learning environments (Ruiz, 2014); STEM technology scratch and Mblock (Gündoğdu & Tunç, 2022); and finally LEGO robotics (Casler-Failing & Swann, 2023). Furthermore, Problem Solving appears in four documents showing that problem solving is also an important topic in learning ratios and proportions. Problem solving presented through the presented problems supports problem-solving skills in middle and elementary school students. The types of technology used are game-based learning such as Boone's Meadow (Bell & Gresalfi, 2017) and E-rebuild (Ke, 2019); Web-Based Platforms in the form of live worksheets (Harini et al., 2023) and STEM technology in the form of Google Forms, YouTube, and Kahoot (Mankhong & Pimvichai, 2024). Finally, Creative Thinking and Communication were found in article A-22. In this study, a STEM technology-based educational approach in the form of Google Forms, YouTube, and Kahoot was used to improve students' creative thinking and communication skills at the junior high school level (Mankhong & Pimvichai, 2024).

CONCLUSION

This study systematically examines the use of technology in learning the topic of ratio and proportion and its impact on students' mathematical abilities. Based on an analysis of 23 relevant articles, it was found that the most dominant technologies used to support this learning were Game-Based Learning (GBL), computer- and web-based technologies, and immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR). These findings are based on empirical evidence showing that GBL, as one of the modern educational trends of the 21st century, plays a significant role in increasing student engagement, while computer- and web-based technologies, as well as VR and AR, provide a more immersive and interactive learning experience. Publication trends related to this topic showed a significant surge in 2023, with the United States and Indonesia dominating research related to the use of technology in learning ratio and proportion. The most dominant type of research was experiments, followed by Research & Development (R&D), which showed a strong focus on testing the impact of technology and developing technology-based learning methods. Based on these findings, further research is recommended to design interventions that integrate technology with local cultural contexts, using a contextual and realistic approach. Furthermore, it is important to consider affective domains, such as self-confidence, motivation, and values, which have not been widely researched but play a crucial role in the use of technology in education. These recommendations aim to create more meaningful, relevant, and accessible learning experiences, and significantly contribute to improving the quality of mathematics learning by utilizing technology effectively and in accordance with students' needs and characteristics.

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